Ministry of Transportation
Ontario

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A REVIEW OF MTO CONCRETE COMPRESSIVE STRENGTH DATA FOR 1991

MATERIALS INFORMATION

ENGINEERING MATERIALS OFFICE

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A REVIEW OF MTO CONCRETE COMPRESSIVE STRENGTH DATA FOR 1991

BY

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ENGINEERING MATERIALS OFFICE
CONCRETE SECTION

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Introduction

The Concrete Section of the Engineering Materials Office receives copies of the 28-day compressive strength tests from throughout the Province. The results are reviewed and analyzed to provide contract, regional and provincial summaries. Most concrete placed on Ministry contracts must meet the requirements of OPSS 1350 in the Ontario Provincial Standard Specifications. One of the requirements of acceptance is based on the results of 28-day compressive strength tests as specified in Section 1350.08.05 of the specifications.

This report provides a summary and review of 28-day compressive strength test results. The summary includes test results of all concrete classes from 15 MPa to 35 MPa. Not included in the report are results on concrete placed on maintenance and municipal contracts or tremie concrete. Only the test results from concrete placed in 1991 are included in the report.

An End Result Specification for concrete has been used on selected contracts in each region. Under the terms of this special provision, concrete is accepted based on a statistical analysis of the mean and standard deviation of all acceptance cylinders in a particular lot.

Results

OPSS 1350 states that a test is defined as the average of two standard 150 mm x 300 mm cylinders. For this report the term "pass" and "fail" have been used. The "pass" term indicates that the results of a single 28-day compressive test (average of two standard cylinders) is greater than or equal to the specified strength. The "fail" term indicates that the result of a single 28-day compressive strength test is less than the specified strength. Table A shows the total number of tests performed in each of the five regions as well as the percentage of the tests that passed and failed. The table also shows the number of tests that were performed under the performance specification including the percentage of tests that passed and failed. In Table B the tests in each region are broken down by concrete class including concrete containing slag cement, fly ash cement, slag - fly ash cement and latex modified concrete. Table C compares the failure rate of all contracts to the failure rate of contracts under the performance specification for the years 1987, 1988, 1990 and 1991.

Figures 1-11 provide a graphical summary of test results by concrete class and type. The figures show the mean and the standard deviation of all test results by contract for each concrete class in the five regions. Actual contract numbers in each region have been replaced with a series of numbers beginning at 1. Contracts that contain less than two results for a given concrete class are not shown in these figures. Appendix A contains the statistics for all test results throughout the Province in tabular form including a list of contracts under the performance specifications.

TABLE A **SUMMARY OF TESTS BY REGION**

REGION	TOTAL NUMBER OF TESTS (Including Performance Specification.)	% PASS	% FAIL
CENTRAL	2021	97.5	2.8
SOUTHWESTERN	476	96.2	3.8
EASTERN	662	95.9	4.1
NORTHWESTERN	286	98.6	1.4
NORTHERN	266	91.7	8.3
ALL REGIONS	3711	96.6	3.4

REGION	NUMBER OF TESTS (Under Performance Specification. Excluding Pavements)	% PASS	% FAIL
CENTRAL	748	98.5	1.5
SOUTHWESTERN	188	99.5	0.5
EASTERN	445	96.2	3.8
NORTHWESTERN	65	100	-
NORTHERN	38	100	-
ALL REGIONS	**1484**	**98.0**	**2.0**

TABLE B SUMMARY OF TESTS BY REGION (NON-SLAG CEMENT, SLAG CEMENT, FLY ASH CEMENT, SLAG - FLY ASH CEMENT, LATEX MODIFIED CONCRETE)

REGION	15 MPa SLAG		20 MPa		20 MPa SLAG		20 MPa FLY ASH		20 MPa SLAG - FLY ASH		25 MPa		25 MPa SLAG	
	#TESTS	% PASS	#TESTS	% PASS	#TESTS	% PASS	#TESTS	% PASS	#TESTS	% PASS	#TESTS	% PASS	#TESTS	% PASS
CENTRAL	1	100	26	100	104	100							85	91.8
SOUTHWESTERN					18	100					18	94.4	31	100
EASTERN					12	100							41	100
NORTHWESTERN			10	100			2	100						
NORTHERN			11	100					7	100	17	100		
ALL REGIONS	1	100	47	100	134	100	2	100	7	100	35	97.1	157	95.5

REGION	30 MPa		30 MPa SLAG		30 MPa FLY ASH		30 MPa SLAG- FLY ASH		30 MPa LATEX MOD.		35 MPa		35 MPa SLAG	
	#TESTS	% PASS	#TESTS	% PASS	#TESTS	% PASS	#TESTS	% PASS	#TESTS	% PASS	#TESTS	% PASS	#TESTS	% PASS
CENTRAL	40	75.0	1241	97.7					62	95.2	5	80.0	457	98.5
SOUTHWESTERN	92	90.2	313	97.4									4	100
EASTERN	31	90.3	368	96.7					7	100			203	94.1
NORTHWESTERN	147	98.6	96	97.9	31	100								
NORTHERN	174	87.9	25	100			32	96.9						
ALL REGIONS	484	88.8	2043	97.1	31	100	32	96.9	69	95.7	5	80.0	664	97.1

TABLE C REVIEW OF FAILURE RATES FOR 1987, 1988, 1990, 1991

YEAR	1987	1988	1990	1991
TOTAL NUMBER OF TESTS	3551	2887	3132	3711
FAILURE RATE (%) (ALL CONTRACTS)	6.2	8.5	5.0	3.4
NUMBER OF TESTS UNDER PERFORMANCE SPECIFICATION	0	643	1357	1484
PER CENT OF TESTS UNDER PERFORMANCE SPECIFICATION	0	22.3	43.3	40.0
FAILURE RATE FOR CONTRACTS UNDER PERFORMANCE SPECIFICATION (%)	-	6.7	2.7	2.0

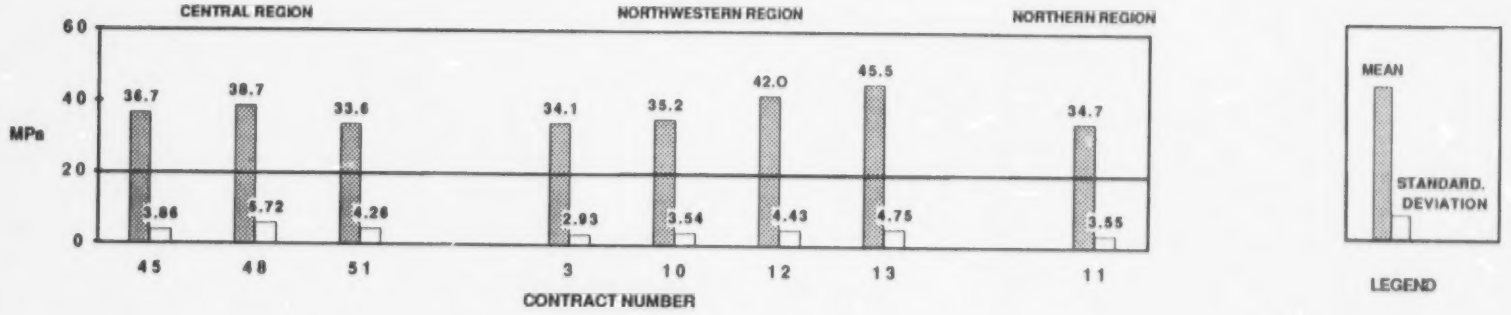


FIGURE 1 : SUMMARY OF TESTS BY CONTRACT - 20 MPa NON-SLAG CEMENT

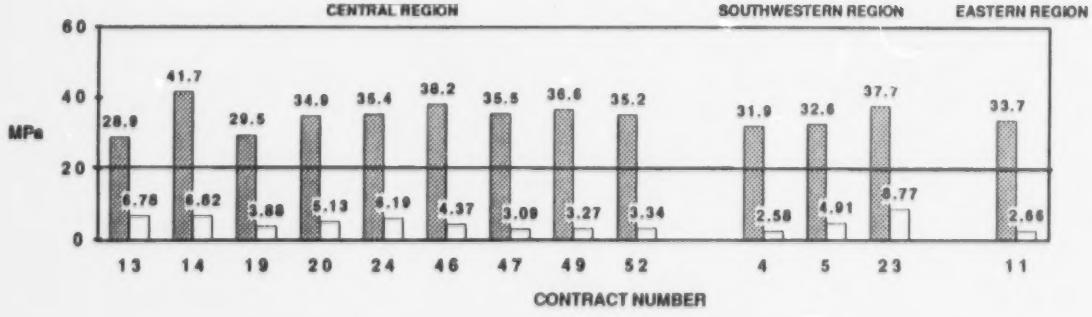


FIGURE 2 : SUMMARY OF TESTS BY CONTRACT - 20 MPA SLAG CEMENT

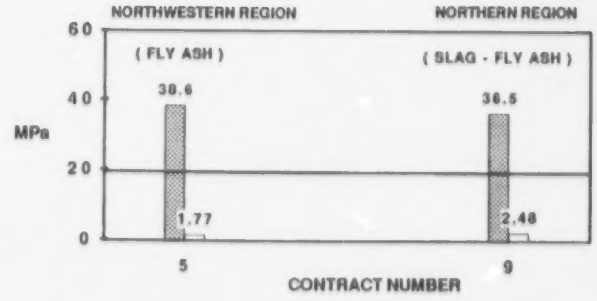


FIGURE 3 : SUMMARY OF TESTS BY CONTRACT
20 MPa CONCRETE

Figure 1 presents the test results for 20 MPa concrete containing no slag cement. The results show that there were no difficulties in meeting the strength requirements by any of the regions.

The summary of test results for 20 MPa class concrete containing slag cement are present in Figure 2. Good compressive strengths were achieved with this class of concrete.

Figure 3 contains the test results for 20 MPa class concrete containing fly ash cement and slag - fly ash cement. The 20 MPa class concrete containing fly ash cement was used only by Northwestern Region while the 20 MPa class concrete containing slag - fly ash cement was used by Northern Region. In both cases no difficulties were encountered by either region in meeting the strength requirements.

Figure 4 summarizes the test results for 25 MPa class concrete containing no slag cement. Only Southwestern and Northern Regions used this class of concrete. 1 test out of 18 tests failed to meet the compressive strength requirements in Southwestern Region. All 17 tests met the compressive strength requirement in Northern Region.

Figure 5 shows the test results for 25 MPa class concrete containing slag cement. This class of concrete was used by Central, Southwestern, and Eastern Regions. While no difficulties were encountered by Southwestern and Eastern Regions in meeting the specified strength, 8.2 per cent out of 85 tests failed to meet the compressive strength requirement in Central Region.

The summary of test results for 30 MPa class concrete containing no slag cement are present in Figure 6. Difficulties with this class of concrete in meeting the strength requirement were experienced by all regions. Out of 484 tests 11.2 per cent failed to meet the specified strength.

Figure 7 presents the test results for 30 MPa concrete containing slag cement. Although difficulties were encountered by all regions with this class of concrete, the test results are more favourable than this class of concrete containing no slag cement. 97.1 per cent out of 2043 tests met the required compressive strength.

Figure 8 contains the test results for 30 MPa class concrete containing fly ash cement, slag - fly ash cement and latex modified concrete. Northwestern Region, the only region to use 30 MPa class concrete containing fly ash cement encountered no difficulties in achieving good compressive strengths. The 30 MPa class concrete containing slag - fly ash cement was only used by Northern Region. One test out of 32 tests failed to meet the required compressive strength. The latex modified concrete was used by Central and Eastern Regions. Central Region had 3 test failures out of 62 tests while Eastern Region had no failures out of 7 tests.

Figure 9 summarizes the test results for 35 MPa class concrete, both non-slag and slag cements. Only Central Region used the 35 MPa class concrete containing no slag cement. 1 test out of 5 tests failed to meet the required compressive strength. No problems were encountered by Southwestern Region with the 35 MPa class concrete containing slag cement. Central Region had 7 test failures out of 203 tests.

A graphical representation for contracts which were under the concrete performance specifications are shown in Figures 10 and 11. All results for a class of concrete were combined for each contract irrespective of the actual number of lots of that type. Mean strengths for the 30 MPa concrete range from 32.2 to 47.7 MPa and the standard deviation ranged from 1.8 to 7.6 MPa. Mean strength for the 35 MPa concrete ranged from 38.7 to 52.3 MPa and the standard deviation ranged from 2.8 to 5.5 MPa.

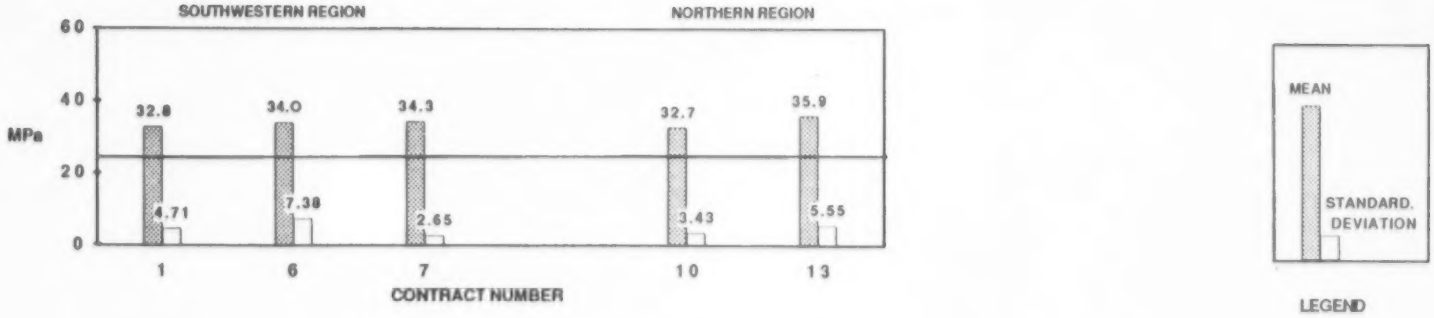


FIGURE 4 : SUMMARY OF TESTS BY CONTRACT - 25 MPa NON-SLAG CEMENT

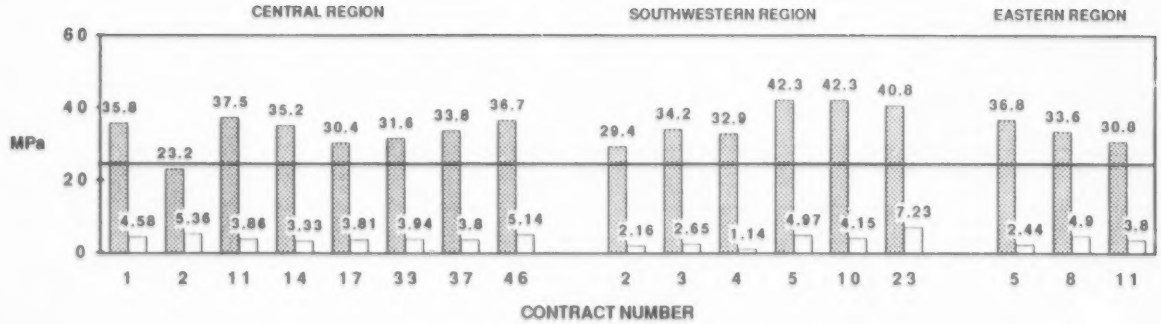


FIGURE 5 : SUMMARY OF TESTS BY CONTRACT - 25 MPa SLAG CEMENT

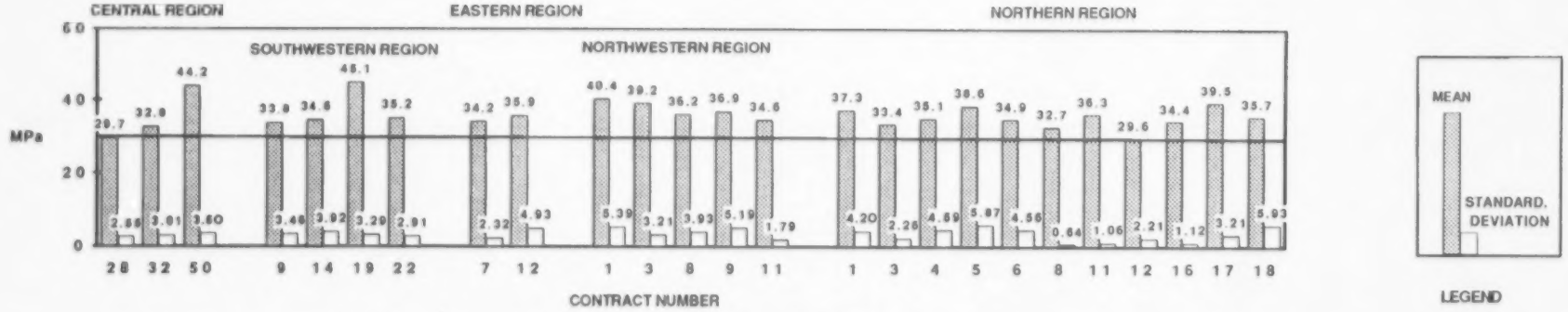


FIGURE 6 : SUMMARY OF TESTS BY CONTRACT - 30 MPa NON-SLAG CEMENT

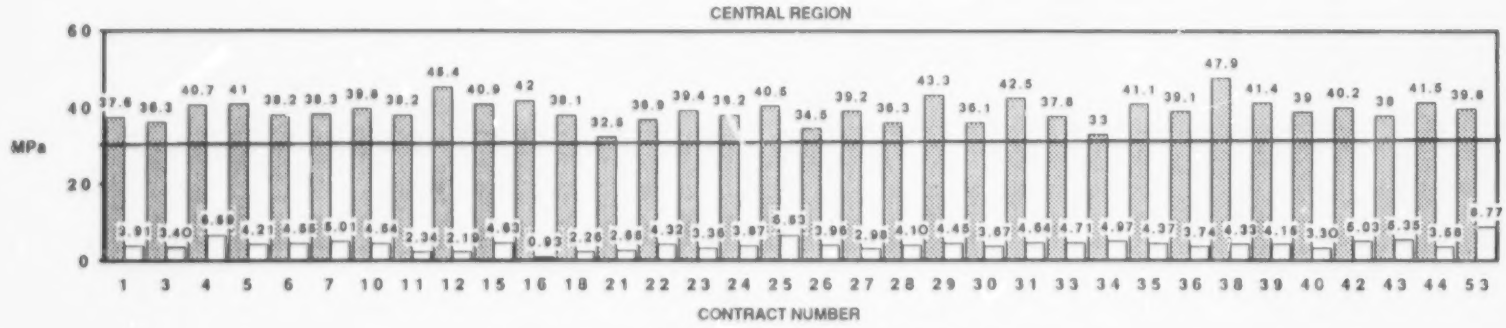


FIGURE 7 : SUMMARY OF TESTS BY CONTRACT - 30 MPa SLAG CEMENT

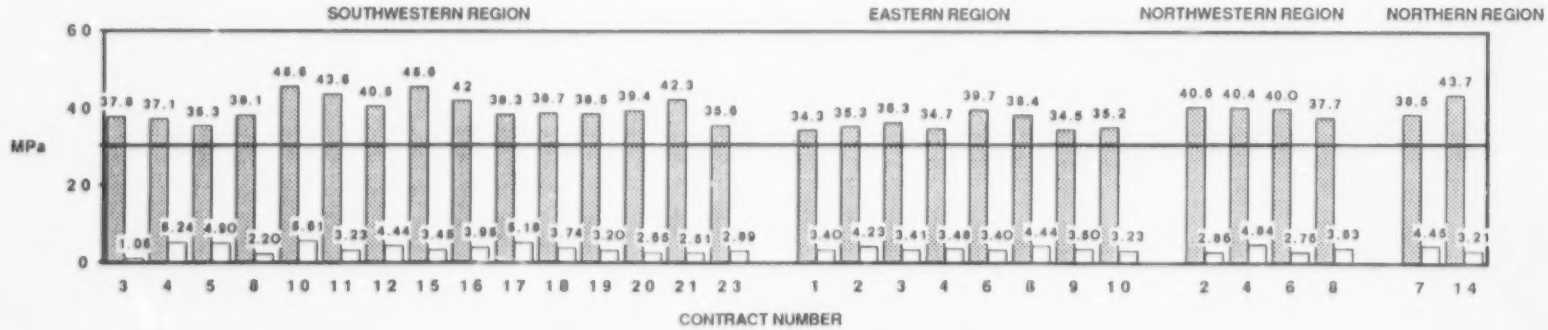
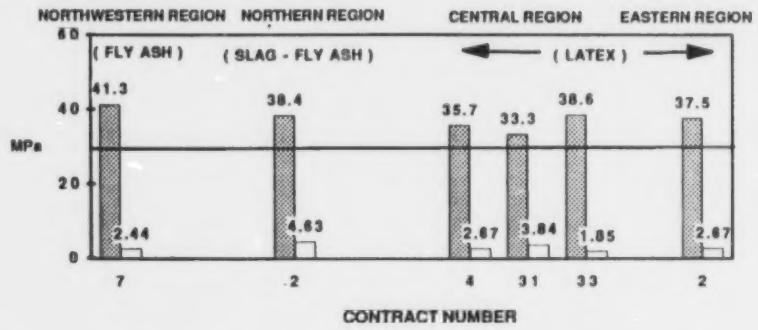
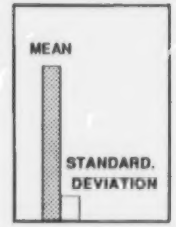

SOUTHWESTERN REGION
EASTERN REGION
NORTHWESTERN REGION
NORTHERN REGION
MPa
60
40
20
0
3 4 5 8 10 11 12 15 16 17 18 19 20 21 23 1 2 3 4 6 8 9 10 2 4 6 8 7 14
CONTRACT NUMBER

FIGURE 7 : SUMMARY OF TESTS BY REGION 30 MPa SLAG CEMENT





LEGEND

FIGURE 8 : SUMMARY OF TESTS BY CONTRACT - 30 MPa CONCRETE

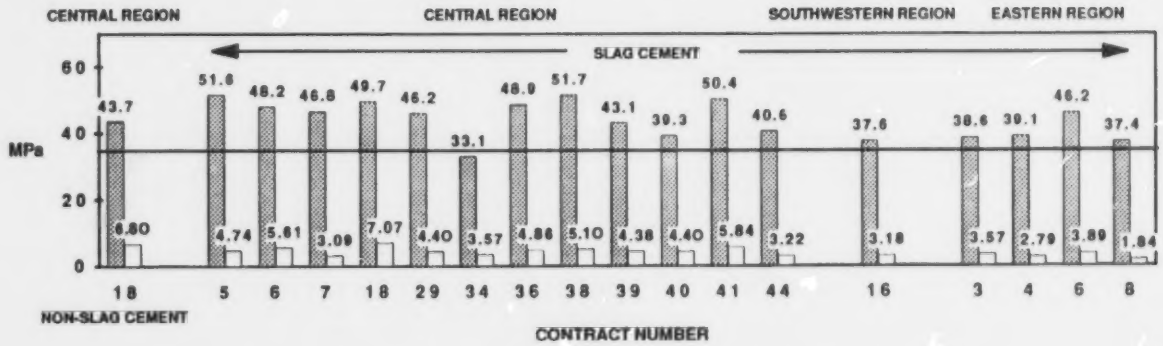


FIGURE 9 : SUMMARY OF TESTS BY CONTRACT - 35 MPA NON-SLAG & SLAG CEMENT

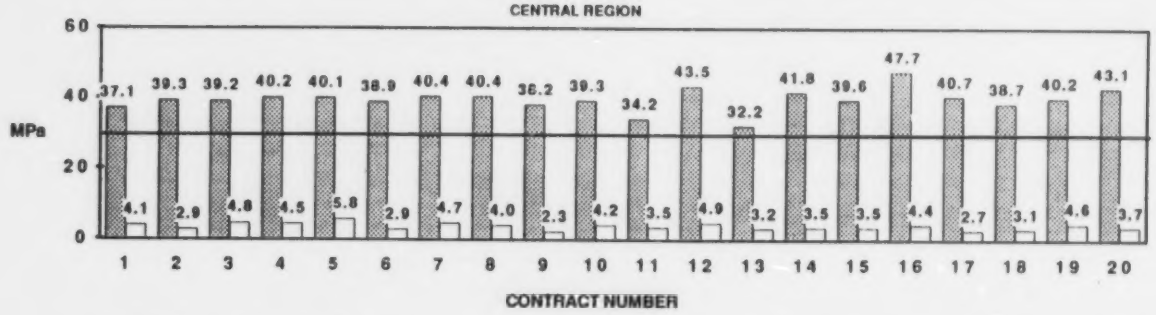


FIGURE 10 : SUMMARY OF TESTS BY CONTRACT UNDER THE PERFORMANCE SPECIFICATION (30 MPa CONCRETE)

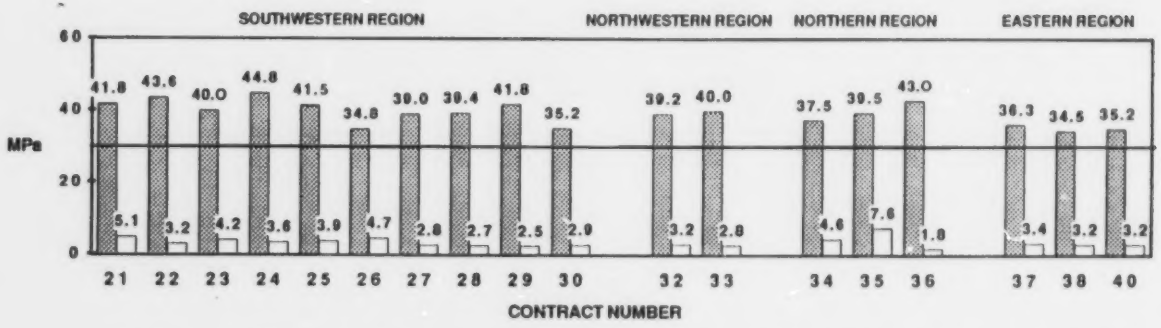


FIGURE 10 : SUMMARY OF TESTS BY CONTRACT UNDER THE PERFORMANCE SPECIFICATION (30 MPa CONCRETE)

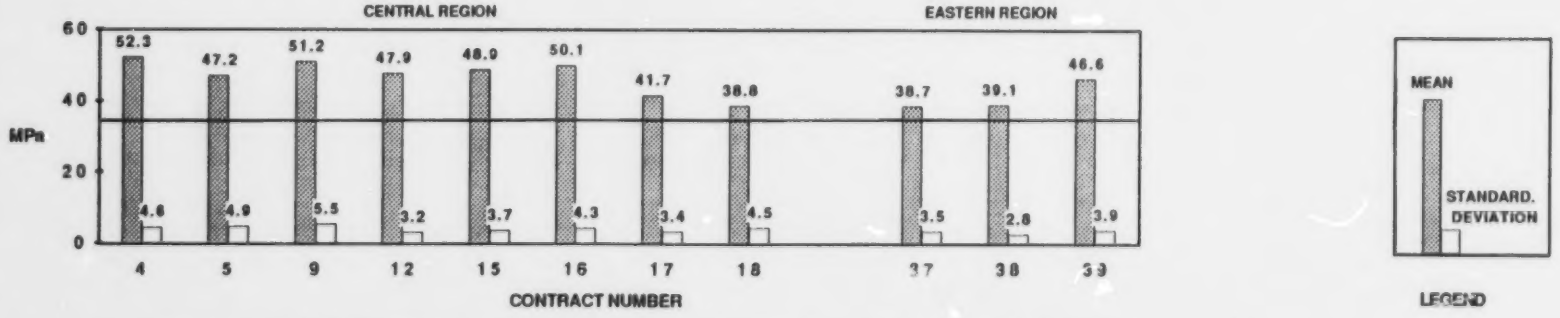


FIGURE 11 : SUMMARY OF TESTS BY CONTRACT UNDER THE PERFORMANCE SPECIFICATION (35 MPa CONCRETE)

Summary

1) Good compressive strengths were achieved with the 15 and 20 MPa class concrete.

2) Minor difficulties were encountered by Central and Southwestern Regions with the 25 MPa class concrete.

3) All regions experienced low compressive strengths with the 30 MPa class concrete, except when slag cement and fly ash cement were used in Northern and Northwestern Regions respectively.

4) Minor difficulties were encountered by Central Region with the latex modified concrete.

5) Some problems were encountered by Central and Eastern Regions with the 35 MPa class concrete.

6) 3711 tests were carried out in 1991 of which 96.6 per cent were greater or equal to the required strength. Under the performance specification 98.0 per cent out of 1484 tests met the required strength.

7) The standard deviation for 30 MPa concrete ranged from 0.6 to 8.8 MPa for all contracts. Under the performance specification the standard deviation ranged from 1.8 to 7.6 MPa. For 35 MPa concrete standard deviation ranged from 1.8 to 7.1 MPa for all the contracts. The standard deviation ranged from 2.8 to 5.5 MPa for performance specification.

8) In 1991, 40 out of 119 contracts contained the performance or "end" result specification for concrete strength. (Special Provision 113 S04).

9) Concrete failure rate is showing a general improvement with time.

Appendix A

Summary of 28-day Compressive Test Results

CENTRAL REGION

CON-TRACT	15 MPa SLAG			20 MPa			29 MPa SLAG			25 MPa SLAG			30MPa			30 MPa SLAG			30 MPa LATEX MOD.			35 MPa			35 MPa SLAG		
	# TESTS	MEAN	ST.DEV.	# TESTS	MEAN	ST.DEV.	# TESTS	MEAN	ST.DEV.	# TESTS	MEAN	ST.DEV.	# TESTS	MEAN	ST.DEV.	# TESTS	MEAN	ST.DEV.	# TESTS	MEAN	ST.DEV.	#TESTS	MEAN	ST.DEV.	#TESTS	MEAN	ST. DEV.
1										16	35.8	4.58				18	37.6	3.91									
2										9	23.2	5.36															
3																8	36.3	3.40							1	46.3	-
4																69	40.7	6.59	38	35.7	2.67						
5																107	41.0	4.21							176	51.6	4.74
6																48	38.2	4.55							69	48.2	5.61
7																11	38.3	5.01							5	46.8	3.09
8																1	36.0	-									
9							1	38.7	-	1	31.0	-															
10																93	39.8	4.54									
11										7	37.5	3.86				4	38.2	2.34									
12										1	46.6	-				6	45.4	2.19									
13							9	28.9	6.78																		
14							25	41.7	6.82	8	35.2	3.33															
15																102	40.9	4.63									
16																3	42.0	0.93									
17										10	30.4	3.81															
18																19	38.1	2.26				5	43.7	6.80	11	49.7	7.07
19							4	29.5	3.88																		
20							4	34.9	5.13							1	39.0	-									
21	1	27.1	-													10	32.5	2.65									
22																43	36.9	4.32									
23																14	39.4	3.36									
24							2	35.4	6.19							29	38.2	3.87									
25																37	40.5	6.53									
26																51	34.5	3.96									
27																21	39.2	2.98									
28													18	29.7	2.55	48	36.3	4.10									
29																75	43.3	4.45							30	46.2	4.40
30																26	36.1	3.67									
31																46	42.5	4.64	14	33.3	3.84						
32													15	32.8	3.01												
33										19	31.6	3.94				19	37.8	4.71	10	38.6	1.85						
34							1	31.0	-							28	33.0	4.97							7	33.1	3.57
35																36	41.1	4.37									
36																80	39.1	3.74							72	48.9	4.86
37										4	33.8	3.80															
38																22	47.9	4.33							29	51.7	5.10
39																65	41.4	4.15							29	43.1	4.38
40																33	39.0	3.30							13	39.3	4.40
41																									11	50.4	5.84
42																18	40.2	5.03									
43																11	38.0	5.35									
44																31	41.5	3.58							4	40.6	3.22
45				8	36.7	3.86																					
46							18	38.2	4.37	9	36.7	5.14															
47							8	35.5	3.09	1	31.7	-															
48				15	38.7	5.72																					
49							21	36.6	3.27							1	37.5	-									
50													7	44.2	3.50												
51				3	33.6	4.26																					
52							11	35.2	3.34																		
53																7	39.8	8.77									

SUMMARY OF 28-DAY COMPRESSIVE STRENGTH TEST RESULTS

SOUTHWESTERN REGION

CONTRACT NO.	20 MPa SLAG			25 MPa			25 MPa SLAG			30 MPa			30 MPa SLAG.			35 MPa SLAG.		
	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV
1				9	32.8	4.71												
2	1	38.7	-				2	29.4	2.16									
3							2	34.2	2.65				2	37.8	1.06			
4	6	31.9	2.58				3	32.9	1.14				21	37.1	5.24			
5	8	32.6	4.91				4	32.7	4.97				33	35.3	4.90			
6				6	34.0	7.38												
7				2	34.3	2.65												
8													10	38.1	2.20			
9										27	33.8	3.46						
10							3	42.3	4.15				14	45.6	5.61			
11													21	43.6	3.23			
12													31	40.5	4.44			
13				1	34.1	-												
14										40	34.6	3.92						
15													44	45.6	3.45	1	43.5	-
16													10	42.0	3.95	2	37.6	3.18
17													29	38.3	5.18			
18	1	31.2	-										29	38.7	3.74			
19										14	45.1	3.29	39	38.5	3.20			
20													8	39.4	2.65			
21													16	42.3	2.51	1	38.3	-
22										11	35.2	2.91						
23	2	37.7	8.77				17	40.8	7.23				6	35.6	2.89			

SUMMARY OF 28-DAY COMPRESSIVE STRENGTH TEST RESULTS

EASTERN REGION

CONTRACT NO.	20 MPa SLAG			25 MPa SLAG			30 MPa			30 MPa SLAG			30 MPa LATEX MOD.			35 MPa SLAG		
	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV
1										64	34.3	3.40						
2										39	35.3	4.23	7	37.5	2.67			
3										179	36.3	3.41				103	38.6	3.57
4										29	34.7	3.48				36	39.1	2.79
5				27	36.8	2.44												
6										5	39.7	3.40				62	46.2	3.89
7							25	34.2	2.32									
8				10	33.6	4.90				12	38.4	4.44				2	37.4	1.84
9										5	34.5	3.50						
10										35	35.2	3.23						
11	12	33.7	2.66	4	30.8	3.80												
12							6	35.9	4.93									

SUMMARY OF 28-DAY COMPRESSIVE STRENGTH TEST RESULTS

NORTHWESTERN REGION

CONTRACT NO.	20 MPa			20 MPa FLY ASH			30 MPa			30 MPa SLAG			30 MPa FLY ASH		
	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV
1							53	40.4	5.39						
2										11	40.6	2.86			
3	2	34.1	2.97				53	39.2	3.21						
4										67	40.4	4.84			
5				2	38.6	1.77									
6										11	40.0	2.76			
7													31	41.3	2.44
8							18	36.2	3.93	7	37.7	3.83			
9							17	36.9	5.19						
10	2	35.2	3.54												
11							6	34.6	1.79						
12	4	42.0	4.43												
13	2	45.5	4.75												

SUMMARY OF 28-DAY COMPRESSIVE STRENGTH TEST RESULTS

NORTHERN REGION

CONT. NO.	20 MPa			20 MPa SLAG - FLY ASH			25 MPa			30 MPa			30 MPa SLAG			30 MPa SLAG - FLY ASH		
	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV
1										35	37.3	4.20						
2																32	38.4	4.63
3										9	33.4	2.26						
4										33	35.1	4.59						
5										9	38.6	5.87						
6										49	34.9	4.56						
7													2	38.5	4.45			
8										2	32.7	0.64						
9				7	36.5	2.48												
10							15	32.7	3.43									
11	10	34.7	3.55							2	36.3	1.06						
12										21	29.6	2.21						
13							2	35.9	5.55									
14													23	43.7	3.21			
15	1	31.4	-							1	33.5	-						
16										3	34.4	1.12						
17										7	39.5	3.21						
18										3	35.7	5.93						

SUMMARY OF 28-DAY COMPRESSIVE STRENGTH TEST RESULTS

SUMMARY OF CONTRACTS UNDER THE PERFORMANCE SPECIFICATION

CONTRACT NO.	30 MPa			35 MPa		
	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV
1	8	37.1	4.1	1	42.7	-
2	8	39.3	2.9			
3	22	39.2	4.8			
4	34	40.2	4.5	153	52.3	4.6
5	18	40.1	5.8	29	47.2	4.9
6	4	38.9	2.9			
7	39	40.4	4.7			
8	62	40.4	4.0			
9	19	38.2	2.3	10	51.2	5.5
10	14	39.3	4.2			
11	31	34.2	3.5			
12	32	43.5	4.9	22	47.9	3.2
13	26	32.2	3.2			
14	7	41.8	3.5			
15	52	39.6	3.5	43	48.9	3.7
16	15	47.7	4.4	16	50.1	4.3
17	22	40.7	2.7	9	41.7	3.4
18	23	38.7	3.1	11	38.8	4.5
19	9	40.2	4.6			
20	9	43.1	3.7			
21	27	41.8	5.1			
22	21	43.6	3.2			
23	27	40.0	4.2			
24	19	44.8	3.6			
25	13	41.5	3.9			
26	12	34.8	4.7			
27	26	39.0	2.8			
28	8	39.4	2.7			
29	24	41.8	2.5			
30	11	35.2	2.9			
31	1	42.1	-			
32	53	39.2	3.2			
33	11	40.0	2.8			
34	15	37.5	4.6			
35	5	39.5	7.6			
36	18	43.0	1.8			
37	179	36.3	3.4	102	38.7	3.5
38	28	34.5	3.2	35	39.1	2.8
39				66	46.6	3.9
40	35	35.2	3.2			